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SURFACE MULCHING WITH COTTON GIN TRASH IMPROVES SANDY SOILS

Conservation Research Report No. 18

CURRENT SERIAL RECORDS
DEC 2 '74

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with
Texas Agricultural Experiment Station
Texas A&M University

CONTENTS

	Page
Summary	1
Introduction	1
Study area	1
Experimental design	2
Procedures	2
Results and discussion	3
Conclusions	10
Literature cited	10

Illustrations

		Page
1.	Measured and computed annual soil losses from Acuff loam soil after three annual applications of cotton gin trash	4
2.	Influence of one and three annual applications of various amounts of cotton gin trash on surface soil aggregation of Acuff loam soil	4
3.	Influence of one application and three annual applications of various amounts of cotton gin trash on the organic matter content of Acuff loam soil at three depths	5
4.	Influence of one application and three annual applications of various amounts of cotton gin trash on the hydraulic conductivity of Acuff loam soil at three depths	6
5.	Influence of one application and three annual applications of various amounts of cotton gin trash on the air porosity of Acuff loam soil at three depths	6
6.	Influence of one application and three annual applications of various amounts of cotton gin trash on the soil bulk density of Acuff loam soil at three depths	7
7.	Influence of annual applications of various amounts of cotton gin trash on soil water storage at various depths in Acuff loam	8
8.	Influence of three annual applications of various amounts of cotton gin trash on diurnal soil temperatures at various depths in Acuff loam	9

Tables

1.	Soil loss per simulated windstorm from an Amarillo loamy fine sand as influenced by cotton gin trash mulch and tillage method	3
2.	Analysis of variance of 1969 data on soil physical properties and change in soil properties between 1967 and 1969	5
3.	Degree-hours above 90° F., July 3–4, 1969, for the four depths and four mulch rates	7
4.	Effect of repeated annual applications of cotton gin trash surface mulch on cotton lint yields	10

Washington, D.C. Issued May 1974

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SURFACE MULCHING WITH COTTON GIN TRASH IMPROVES SANDY SOILS

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SUMMARY

Annual application of 5 tons/acre or more of cotton gin trash on the surface of a sandy soil controlled wind erosion, improved soil-water-air relations, and increased cotton lint yields. The surface mulch reduced soil temperatures to a depth of 30 inches and bulk density to a depth of 7.5 inches. However, it increased air capacity and total porosity of the surface 3 inches, increased hydraulic conductivity and organic matter to a depth of 12 inches, increased soil water storage to a depth of 10 feet, and increased cotton lint yields 16 to 36 percent. The drier the year, the greater the increase. Mulch at 2.5 tons/acre was insufficient to control wind erosion.

INTRODUCTION

The Southern Plains region served by the Big Spring (Tex.) Field Station of the U.S. Department of Agriculture has been transformed from a grazing area at the time the country was settled in the 1870's to one intensively cultivated in the mid-1940's to an area with diversified farming and ranching today. The hazard of the wind blowing the sandy soils was apparent during droughts in 1894, 1917, the 1930's, and the early 1950's. Conservationists realized that something must be done to reduce wind erosion and to improve the soil-water relations of dryland sandy soils. Plowing 18 to 24 inches deep was thought to be the answer in areas of shallow clay layers. An evaluation of deep plowing after 2 or 3 years revealed that some sandy soils were as erodible as before plowing (*5*).[1] The silt and clay fractions of the surface soil were blown away, and the water-holding capacity and productivity of the soil were thus reduced. The problem of cultivating sandy soils without increasing their susceptibility to wind erosion was not solved. Research conducted by the Big Spring Field Station from 1967 to 1971 to determine if a surface mulch of cotton gin trash would reduce the erodibility of sandy soils and improve their soil-water relations is reported in this paper. The quantity of cotton gin trash may be limited, but all organic surface mulches have similar soil-improving qualities.

[1] Italic numbers in parentheses refer to items in "Literature Cited" p. 10.

STUDY AREA

Location

The study area is located north of Big Spring, Tex., on the southern edge of the Texas High Plains. It is at the confluence of the High Plains, the Rolling Red Plains, and the Edwards Plateau (latitude 32° 10′, longitude 101° 30′; elevation 2,400 feet mean sea level). The Edwards Plateau, to the south, is predominately rangeland, while the High Plains to the north and northwest is primarily cultivated land. There are over 6 million acres of sandy soils in the southern part of the Texas High Plains. Most of this area is farmed without irrigation or with only limited irrigation. The Rolling Plains to the east includes both rangeland and cultivated land. The research at the Big Spring Field Station is applicable to all sandy soils

Soils

The soils in the High Plains have been described by Burnett et al. (*3*) as typically brown to reddish-brown, friable, neutral, fine sandy loam, but loamy fine sand and sandy clay loam also occur. The surface layer, usually about 8 to 15 inches thick, grades into reddish-brown, neutral-to-alkaline, friable, sandy clay loam subsoil of weak prismatic and subangular blocky structure. About 40 to 70 inches below the surface the subsoil grades into a highly calcareous, pink, soft, sandy clay loam substratum ($CaCO_3$, or caliche, layer about 20 inches thick), below which lies the less limy, reddish-brown to pink, sandy clay loam parent soil. Most soils in the High Plains are members of a fine-loamy, mixed-thermic family of the Aridic Paleustolls or Aridic Paleustalfs.

Climate

The Southern Plains climate is characterized by wide extremes of rainfall and temperature. Years with abnormally high rainfall may be preceded or followed by years with below-normal rainfall. Winter is usually dry, but spring and fall are relatively wet, and prolonged droughts are not uncommon. Winter (November through March) is characterized by frequent dry cold fronts accompanied by gusty southwesterly to westerly winds. These winds may kick up huge clouds of dust that last from a few minutes to several days. Since the major crop is cotton, which produces little surface residue, the erodible sandy soils are bare in winter and spring and unprotected from wind erosion.

Rainfall, although reasonably well distributed, may come in intense thunderstorms leaving 1.5 or 3 inches of rain in 1 hour (*9*). The bare soils are easily eroded by runoff water, so a double loss occurs—loss of topsoil and loss of valuable water.

EXPERIMENTAL DESIGN

Experiment I was designed to determine the amount of cotton gin trash needed to control wind erosion and the tillage method required to anchor the gin trash (*7*). The experimental design was randomized, with a factorial arrangement of the treatments. The mulch rates were 0, 1, 3, 5, 7, and 10 tons/acre. The tillage treatments were no tillage (flat), listing, and chiseling before and after the application of gin trash. The tillage and mulching treatments were applied in January 1967. Each plot consisted of ten 40-inch rows, 15 feet long, on an Amarillo loamy fine sand soil. The plots were tested for erodibility with a portable wind tunnel 6 weeks after the mulch treatments had been applied.

Experiment II was designed to evaluate the influence of four annual applications of cotton gin trash on soil water storage, cotton lint yields, and water use efficiency by cotton and to measure changes in the physical properties of an Acuff loam soil (formerly mapped as Amarillo sandy clay loam). A factorial design with three replications was used for this field plot study. Four rates of mulch (0, 2.5, 5, and 10 tons/acre) were applied following the winter seedbed preparation, which consisted only of chiseling the rows. Each plot consisted of six 40-inch rows, 120 feet long.

PROCEDURES

Wind Tunnel

A portable wind tunnel (*2*), 36 inches wide and 24 feet long, was used to simulate a wind velocity of 35 m.p.h. at a height of 24 inches (equivalent to 55 m.p.h. at 50 feet) for 5 minutes. Two percent of the soil eroded from a plot was obtained as an aliquot sample for estimating the erodibility of the treatment. Wind profiles were obtained at the outlet end of the tunnel, and all the measured soil losses were adjusted to an equivalent soil loss for a drag velocity of 108 cm./sec. (2.39 m.p.h.) (*6*).

Dry-Aggregate Stability

Dry-aggregate analyses were run on the surface inch of soil with Chepil's (*4*) rotary-sieve technique. The percentage of the sample passing through a 0.84-mm. sieve was considered as the erodible fraction of the sample. The samples were taken in February 1968 and February 1970. They were ovendried at 105° C, and then sieved. The sieve sizes were 0.42, 0.84, 2.38, 6.4, and 12.7 mm.

Organic Matter

The organic matter in the surface soil samples was determined by the modified wet-oxidization procedure outlined by Allison (*1*). A blank sample without soil was run as a check. The 1967 samples were taken before the mulch was applied. The 1969 samples were taken after two applications of mulch.

Soil Water

Changes in soil water content were determined quarterly by the neutron-scattering technique in 8-inch increments to a depth of 120 inches. Access tubes were installed in the plots treated with 0, 5, and 10 tons/acre of mulch.

Soil Temperatures

Soil temperatures were measured with thermocouples and a recording potentiometer at 0.5-, 2-, 8-, and 30-inch depths. The readings were taken at 30-minute intervals for selected 24-hour periods during the cotton-growing season.

Hydraulic Conductivity

Before initiation of the study in 1967, undisturbed cores, 2.0 by 1.5 inches, were taken from each plot at 0.0- to 3-, 3- to 6-, and 9- to 12-inch depth increments. Undisturbed cores from the same depths were taken again in October 1969. The sample weights and soil water content were

recorded, and the samples were wet from the bottom of the core to minimize entrapped air. The saturated hydraulic conductivities at 20° C. were determined with a 0.79-inch head of water on the top of the core.

Pore Size, Bulk Density, and Crop Yields

The total porosity and bulk density were determined from wet and dry weights based on a sample volume of 4.37 cu. in. Cotton lint yields were obtained from experiment II by hand harvesting the two center rows of the six-row plots.

RESULTS AND DISCUSSION

Wind Erosion

In the first experiment it was assumed that the soil loss due to one treatment with the wind tunnel was equivalent to the soil loss from one natural windstorm. Given this assumption, the loss from a bare, flat, unmulched, loamy fine sand was 55 tons/acre/year, compared with an assumed allowable soil loss of 4 tons/acre/year. The allowable soil loss is the estimated annual soil loss that can be tolerated without reducing the productive capability of the land. The allowable soil loss per storm is 285 lb./acre/storm if 28 dust storms per year are assumed.

The cotton gin trash mulch reduced soil loss at all rates of application (table 1). The application of 1 ton/acre of gin trash reduced soil losses 43 percent, but the soil loss was still greater than the allowable soil loss. At 5 tons/acre, mulch reduced soil losses below the allowable loss of 4 tons/acre/year. The 7 and 10 ton/acre mulch rates further reduced soil loss, but reductions were not significantly different from losses at the 5 ton/acre rate.

At the 1 or 3 ton/acre mulch rates, the soil surface was not completely covered, and sand drifting from the intervening bare areas was trapped by clumps of trash. The trapped sand prevented the trash clumps from blowing away, but served as a source of loose sand whenever the wind direction changed.

Listing, or bedding, significantly reduced soil losses from bare soil, but chiseling the soil did not reduce soil losses compared with the no-tillage treatment (table 1). The soil loss from tillage treatments with more than 5 ton/acre of cotton trash was greater than from the no-tillage treatment; however, they are well below the allowable soil loss rate. The increase in surface roughness, associated with the tillage treatments, and difficulties in getting a uniform and complete soil cover may account for some variation in soil loss. Care should be exercised in interpreting the data in table 1 because the wind tunnel blew perpendicularly to the row direction; therefore, winds parallel to the row direction may increase soil losses on tilled plots. The magnitude of the increase would be different for the various tillage treatments, but could be greatest for the listed plots.

In the second experiment, mulch rates of 0, 2.5, 5, and 10 tons/acre were used to evaluate the influence of repeated applications of cotton gin

TABLE 1.—*Soil loss per simulated windstorm from an Amarillo loamy fine sand as influenced by cotton gin trash mulch and tillage method (experiment I)*

Mulch rate (tons/acre)	Soil loss by tillage method				
	Listing	Chiseling[1]	Chiseling[2]	Flat	Mean loss
	Lb./acre	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*
10	114	34	19	17	46a
7	90	90	182	69	108
5	236	213	545	136	282ab
3	409	536	1,154	554	663b
1	491	1,173	1,691	2,291	1,411c
0	536	1,791	1,982	4,182	2,122d
Mean loss[3]	313a	640ab	929ab	1,208b	.....

[1] Chiseled after the application of gin trash.
[2] Chiseled before the application of gin trash.
[3] Means followed by different letters are significantly different at the 5-percent level. Mulch LSD (least significant difference) 422 lb./acre; tillage LSD 636 lb./acre.

trash on the erodibility of an Acuff loam soil. The wind tunnel tests were made in midwinter before the fourth mulch application. The "measured" curve in figure 1 shows that continued application of 4 tons/acre of cotton gin trash to a flat surface is needed to keep the annual soil loss from wind erosion below the allowable level. The computed soil loss, calculated with the wind erosion equation (*11*) and estimates of surface roughness, surface residue, and the measured soil surface aggregates, agrees closely with the measured soil losses. Both the measured and computed curves show the leveling off of annual wind erosion loss at mulch rates in excess of 5 tons/acre.

The widespread use of gin trash may be restricted by its limited quantity. However, many fields with isolated knolls or extremely erodible sandy areas could be spot-treated with cotton gin trash or other organic mulch. With wind erosion controlled on these trouble spots, entire fields might be protected.

Dry-Aggregate Stability

Since the first samples were taken 1 year after the first mulch application, the importance of the 1968 dry-aggregate analyses cannot be clearly

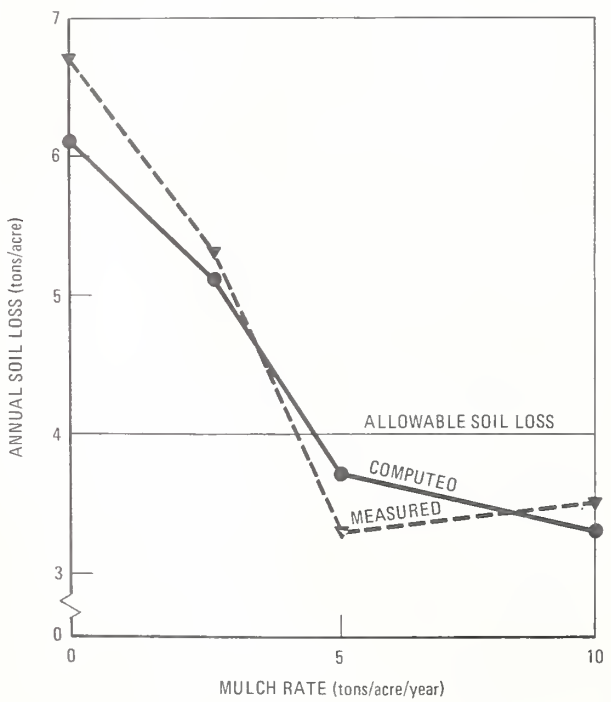

FIGURE 1.—Measured and computed annual soil losses from Acuff loam soil after three annual applications of cotton gin trash.

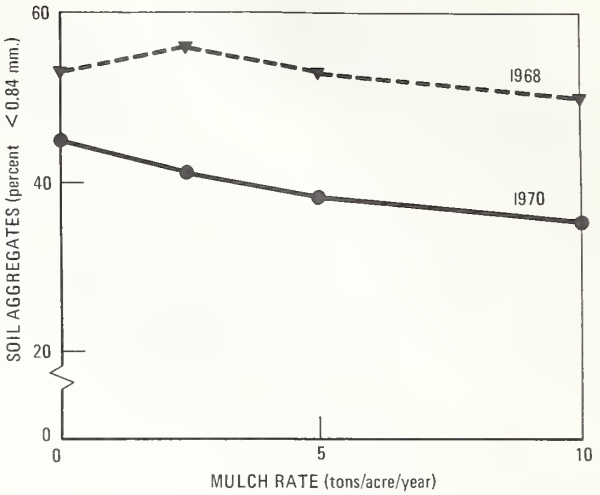

FIGURE 2.—Influence of one (1968) and three (1970) annual applications of various amounts of cotton gin trash on surface soil aggregation of Acuff loam soil.

stated (fig. 2). The 1970 samples are from the same location; therefore, any change in aggregation between 1968 and 1970 should have been due to the mulch. The mulch treatments resulted in 3.1 to 8.5 percent less erodible soil aggregates than the no-mulch treatment. The decrease in erodible soil aggregates for the no-mulch treatment may have been due to reduced traffic on the study area. The significant decrease in erodible fractions would help reduce wind erosion from these soils. The decrease in erodible aggregates is the reason that the computed wind erosion loss is less on the mulched plots (fig. 1).

Organic Matter

In 1967 before any mulch was applied, the average organic matter (OM) content of the surface soil in all plots was 0.69 percent. After three annual mulch applications, the plots receiving 10 tons/acre of mulch had more OM in the surface 3 inches than those receiving 5, 2.5, and 0 tons/acre (fig. 3).

The change in OM between 1967 and 1969 was analyzed by analysis of variance (table 2). The OM increased with increasing mulch rate and decreased with depth. The increase in OM at the various mulch rates was similar at the three depths. The difference between 5 and 2.5 tons/acre was not significant, but both mulch treatments resulted in more OM than the no-mulch treatment. The average OM content of the entire study area increased 30 percent during the 3-year period.

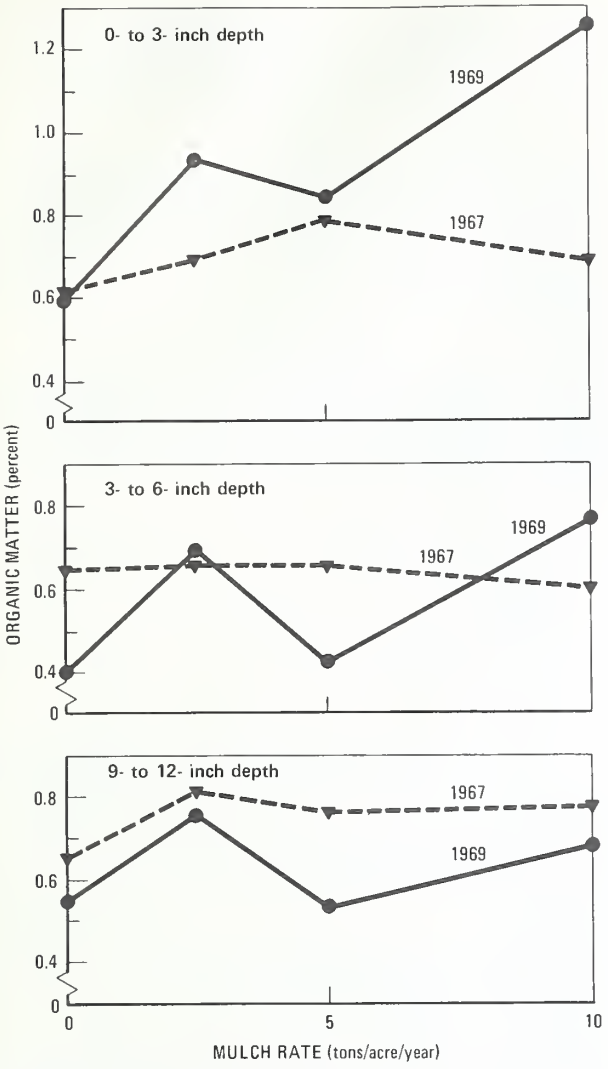

FIGURE 3.—Influence of one application (1967) and three annual applications (1969) of various amounts of cotton gin trash on the organic matter content of Acuff loam soil at three depths.

The average OM content at the 3- to 6-inch depth declined between 1967 and 1969. The OM content at the 3- to 6-inch depth varied with mulch rate, but increased at the 10 ton/acre rate.

The OM content at the 6- to 12-inch depth declined between 1967 and 1969, with the largest decrease occurring at the 5 ton/acre rate.

Each data point in figure 3 is the average of 36 samples. The variability was not great, and the mulch-depth interaction for the change in OM between 1967 and 1969 was significant (table 2.) The variation in OM response to the various mulch rates may be the result of a complex interaction among OM, hydraulic conductivity, air porosity, and bulk density. A carefully controlled study would be required to determine the exact relation among OM, hydraulic conductivity, air porosity, and bulk density.

Hydraulic Conductivity

Before the first mulch application in 1967, the overall hydraulic conductivity was 0.52 inch/hour. After 3 years of mulching, the average hydraulic conductivity of the surface 3 inches was 1.60 inches/hour, or three times greater than before treatment (fig. 4). Mulching with 10 tons/acre significantly increased the hydraulic conductivity above the three lower mulch rates (table 2).

The average hydraulic conductivity of the treated plots at the 3- to 6-inch depth increased threefold above pretreatment values. The hydraulic conductivities resulting from all three mulch applications increased over that of the no-mulch treatment, but differences among the three mulch rates were not significant. The hydraulic conductivity in 1969 at the 9- to 12-inch

TABLE 2.—*Analysis of variance of 1969 data on soil physical properties and change in soil properties (CSP) between 1967 and 1969*

Variant	Degrees of freedom	*F* values							
		Bulk density		Organic matter		Hydraulic conductivity		Air porosity	
		1969	CSP	1969	CSP	1969	CSP	1969	CSP
Replications	2	1.52	1.52	6.83**	6.84	0.31	0.31	5.16**	5.16**
Mulch	3	7.16**	7.24**	13.69**	12.25**	3.72*	6.02**	3.14*	3.42*
Depth	2	26.55**	6.09**	18.77**	18.84**	13.43**	12.85**	.56	.26
Much × depth	6	3.81**	6.55**	1.98	2.25*	.55	.57	1.56	2.29*
Error	129	.....	.....	.....	.....	.....	.....	.....	.....

* Significant at 5-percent level.
** Significant at 1-percent level.

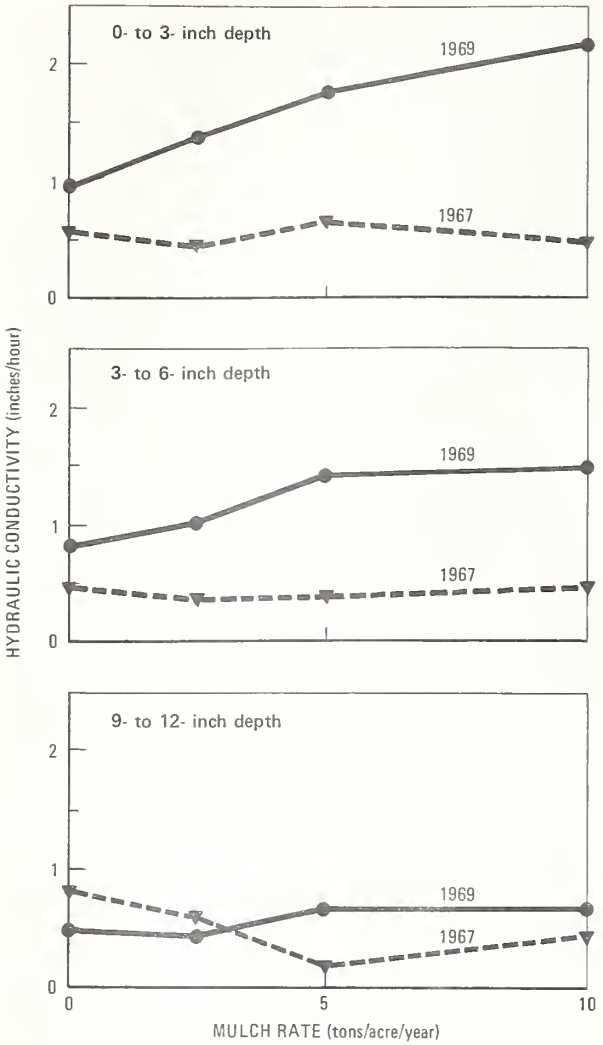

FIGURE 4.—Influence of one application (1967) and three annual applications (1969) of various amounts of cotton gin trash on the hydraulic conductivity of Acuff loam soil at three depths.

depth was one-third the surface hydraulic conductivity, but was not significantly influenced by the mulching treatments.

Porosity

Mulching increased the porosity in the surface 3 inches (fig. 5). The porosity increased at all depths, but the change in porosity with depth between 1967 and 1969 was not significant (table 2). The increased total porosity was primarily the result of an increase in air porosity and not an increase in capillary porosity.

Bulk Density

The plots that had received 10 tons/acre of gin trash mulch for 3 consecutive years had the lowest bulk densities in the surface 3 inches (fig. 6). Plots receiving 5 tons/acre of mulch had lower bulk densities than either the 0 or 2.5 tons/acre mulch plots.

At the 3- to 6-inch depth, bulk density was reduced at the 5 and 10 ton/acre rates, but was not changed at the low mulch rate. Densities at the 9- to 12-inch depth in all plots were lower in 1969, but there was not significant difference among mulching rates.

Soil Water

During the noncropped period the plots mulched at 5 and 10 tons/acre stored significantly more water than the unmulched plots (fig. 7). At

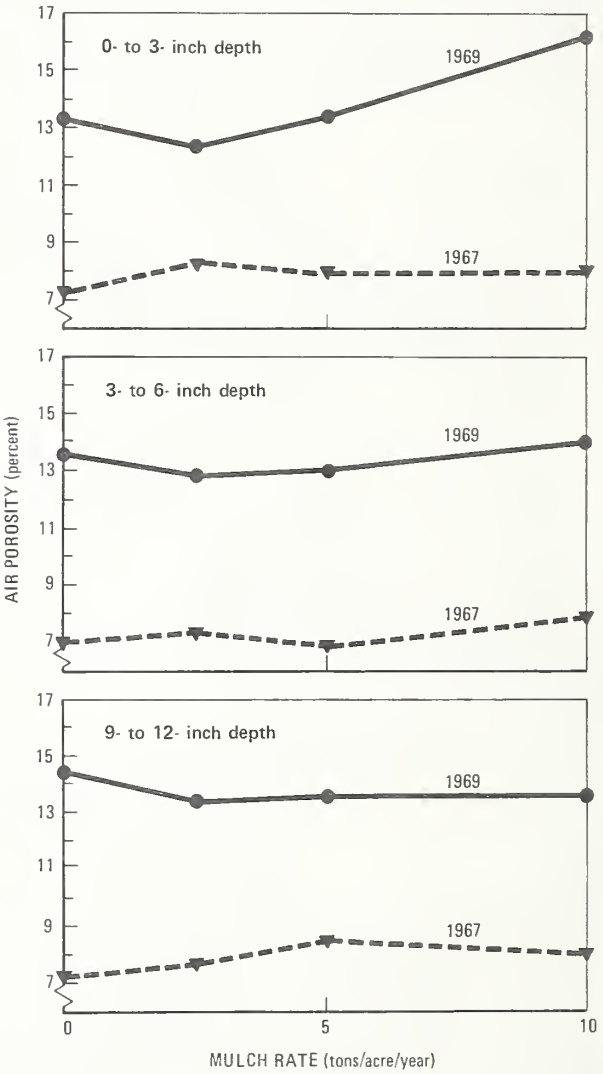

FIGURE 5.—Influence of one application (1967) and three annual applications (1969) of various amounts of cotton gin trash on the air porosity of Acuff loam soil at three depths.

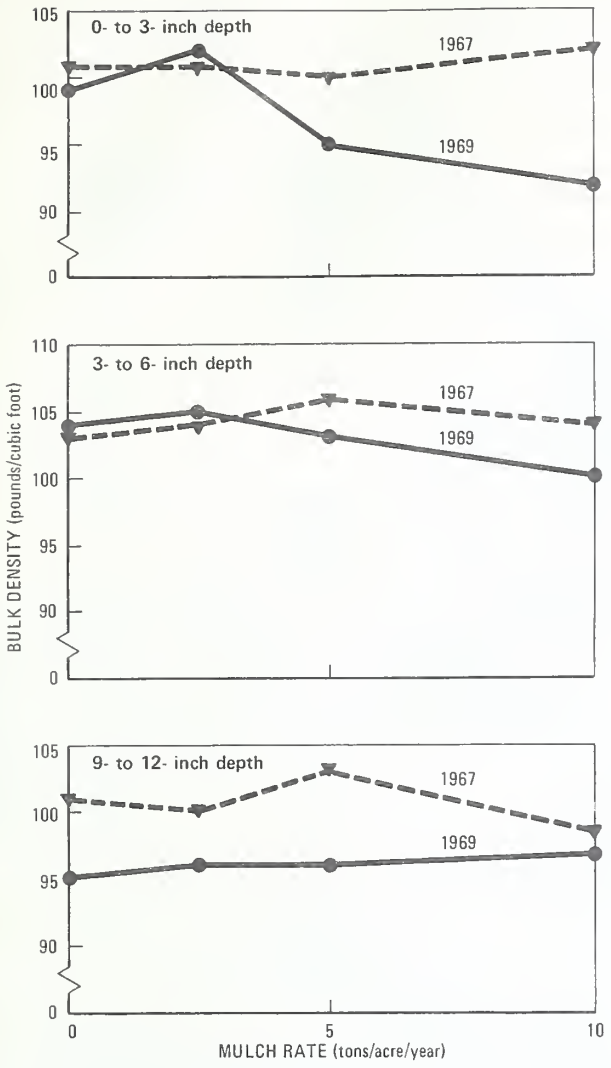

FIGURE 6.—Influence of one application (1967) and three annual applications (1969) of various amounts of cotton gin trash on the soil bulk density of Acuff loam soil at three depths.

the 10 ton/acre mulch rate the soil stored more water in the wetter years and about the same as stored at the 5 ton/acre rate in the dry years. Evidently, the 5 ton/acre rate results in more efficient storing of water than the 10 ton/acre rate when rains consist of small showers. Without mulch, there was little accretion and depletion of water below the 6-foot depth. When the soil surface was covered with mulch, water was stored and eventually depleted from a depth of at least 8 feet. The soil water depleted from the mulched versus the unmulched plots is not as consistent as the accretion because of a rainy period at the end of the growing season in September 1969. The deep depletion of stored water was either used by the cotton or lost to percolation below the 10-foot depth.

Soil Temperatures

The temperature curves in figure 8 were taken when no rainfall had occurred for 18 days. There was little difference in the minimum temperatures at the ½-inch depth of all plots, but the maximum temperatures of the unmulched plots were 5 to 10 degrees above the mulched plots. The same trend was true for the 2- and 8-inch depths.

A surface mulch can influence soil temperatures by (1) changing the albedo, (2) serving as insulation, (3) changing the thermal diffusion characteristics of the soil, or (4) a combination of these factors.

One way to check the overall effect of the mulch is to determine the time-temperature relations of the mulches at various depths. A higher temperature for a long period of time may increase the evaporation of water from the soil. To determine the difference in the heat load for the various mulch rates the degree-hours above 90° F. was determined (a temperature of 110° F. for 2 hours would give 40 degree-hours). The degree-hours/day for the mulched plots are less than those for unmulched plots (table 3). The lower values for the 2.5 ton/acre plots compared with the 5 ton/acre plots may be the influence of the mulch on the soil color. The decomposing mulch on the 5 ton/acre plots visibly darkened the soil surface. The 10 ton/acre plots were also darker, but there was more of an insulating blanket of mulch on the soil surface.

Crop Yield

Cotton lint yields increased 10 to 67 percent after an annual application of 2.5 to 10 tons/acre of gin trash (table 4). There was no apparent additive effect of mulching beyond 3 years because the percentage increase in cotton yield remained relatively constant the fourth year. In

TABLE 3.—*Degree-hours above 90° F., July 3–4, 1969, for the four depths and four mulch rates*

Depth (inches)	Mulch rate (tons/acre/year)			
	0	2.5	5	10
	Degree-hours			
0.5	200	108	138	85
2	98	41	70	24
8	11	1	13	0
30	0	0	0	0

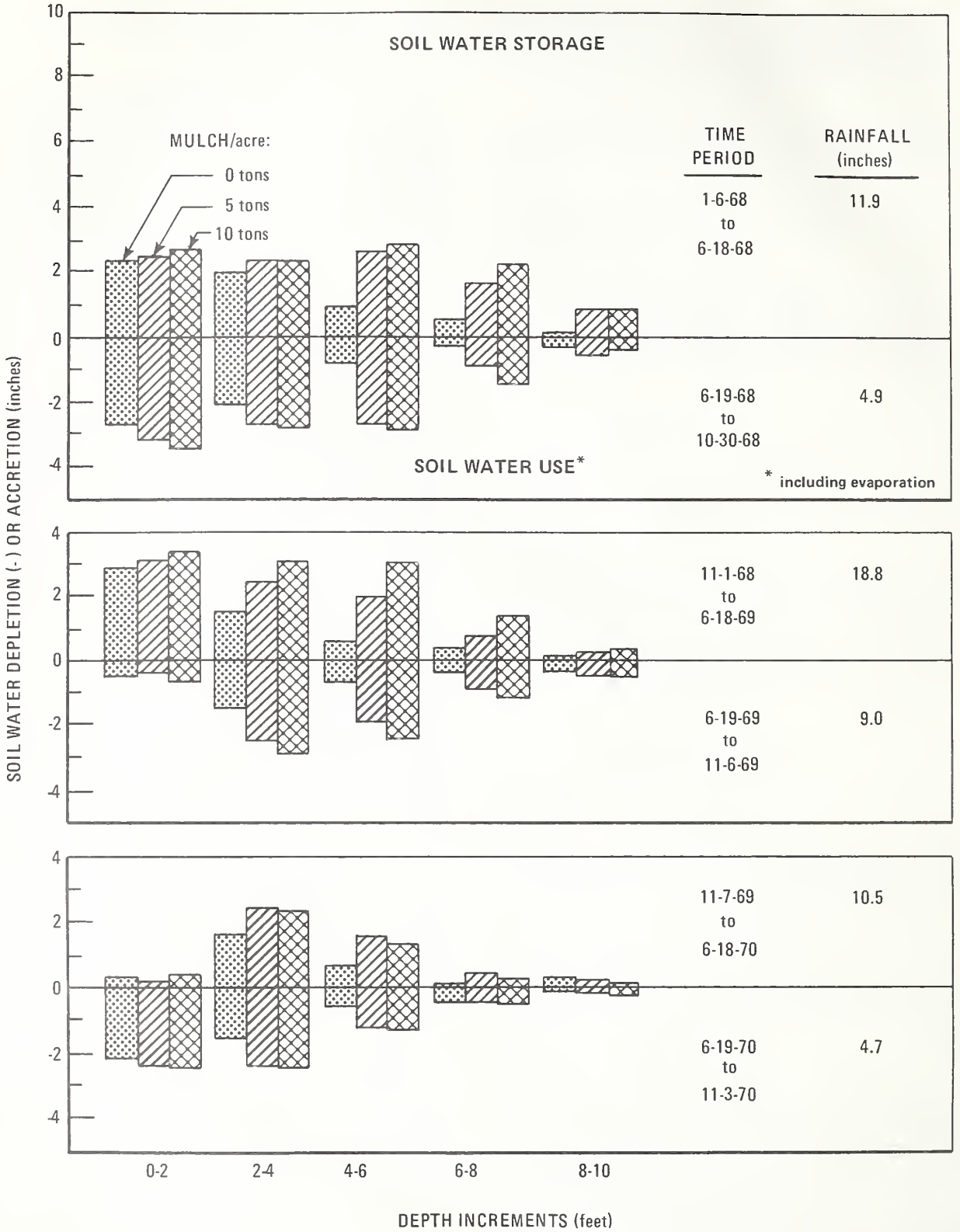

FIGURE 7.—Influence of annual applications of various amounts of cotton gin trash on soil water storage at various depths in Acuff loam.

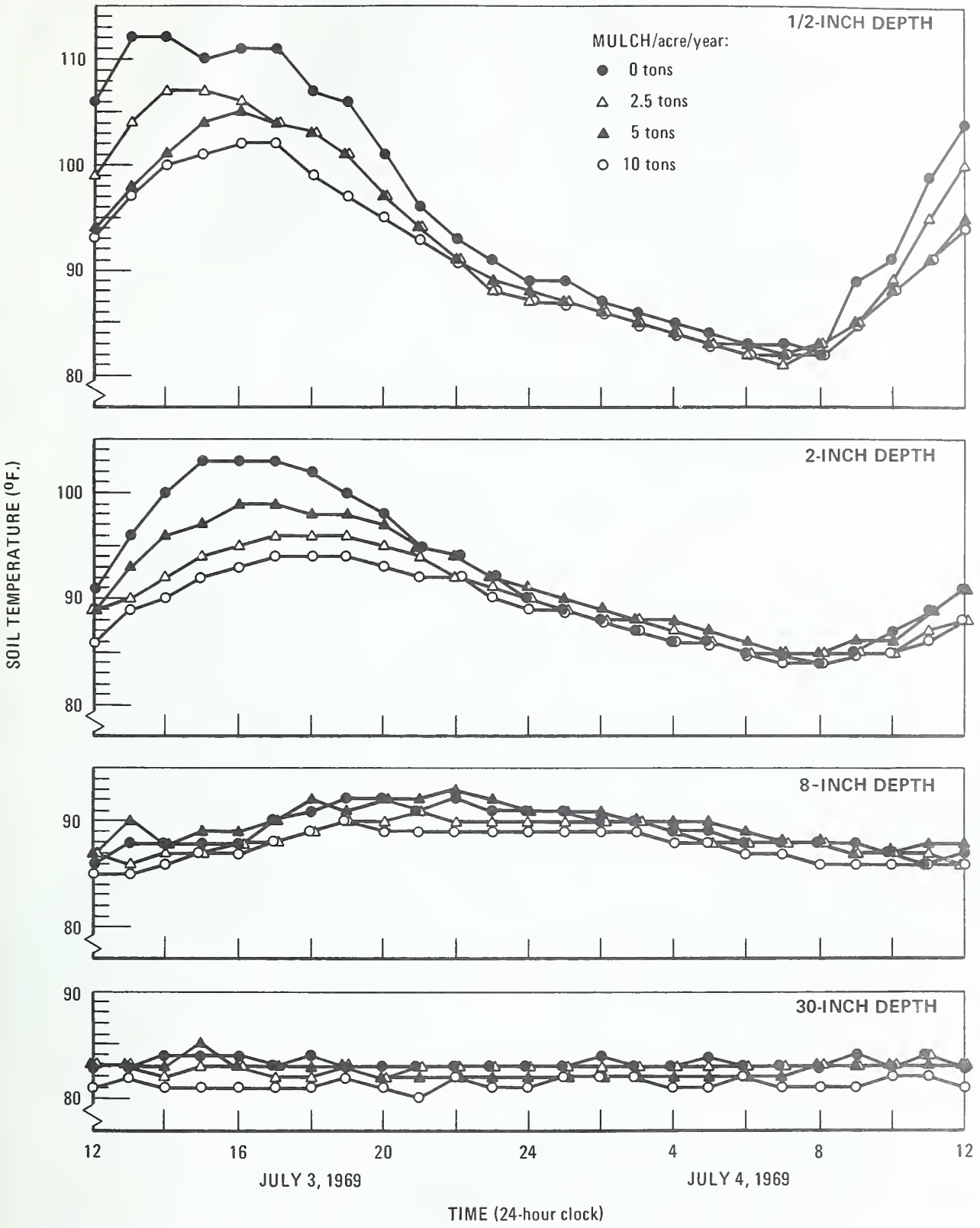

FIGURE 8.—Influence of three annual applications of various amounts of cotton gin trash on diurnal soil temperatures at various depths in Acuff loam.

TABLE 4.—*Effect of repeated annual applications of cotton gin trash surface mulch on cotton lint yields*

Mulch (tons/acre/year)	Cotton lint yields				
	1967	1968	1969	1970	Average
	Lb./acre	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*
10	635	365	190	260	362
5	590	390	170	235	346
2.5	525	335	140	235	309
0	480	270	115	195	265
Average	558	340	154	231	320

1969 the percentage increase from the mulched plots was larger, but overall production was below normal. This indicates a greater response to mulching in dry years. The water use efficiency of the cotton was not affected by the surface mulch.

CONCLUSIONS

Applying 5 tons/acre of cotton gin trash in the winter will protect sandy soils from wind erosion the following spring provided it is left on the soil surface. Applying 5 tons/acre annually for 3 years increased the stability of the surface soil aggregates enough to control wind erosion year-around.

Leaving the mulch on the soil surface will increase cotton lint yields, particularly in dry years. The surface mulch did not increase the efficiency of water use by the cotton plant, but there was more available water under the mulched plots. Similar results have been reported with other organic surface mulches (*8*). Farmers can also increase the storage of water in the soil during noncropped periods of the year and reduce the bulk density of the soil with a surface mulch. Reducing the bulk density and increasing the soil water content with a surface mulch will lower the power required to till the soil (*10*) and will improve the soil-air-water relations of sandy soils.

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U.S. GOVERNMENT PRINTING OFFICE : 1974 O—536–210